IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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SERIAL NO.: 10/799,309 GROUP ART UNIT: 2814

FILING DATE: March 12, 2004 EXAMINER: W. Louie

TITLE: LIGHT-EMITTING DEVICE, LIGHT-EMITTING APPARATUS, IMAGE DISPLAY APPARATUS, METHOD OF MANUFACTURING LIGHT-EMITTING DEVICE, AND METHOD OF MANUFACTURING IMAGE DISPLAY APPARATUS

Hon. Commissioner of Patents and Trademarks,
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S I R:
CERTIFIED TRANSLATION

I, Masaaki Iwami of 3-22, Asagaya-minami 1-chome, Suginami-ku, Tokyo, Japan, am an experienced translator of the Japanese language into the English language and I hereby certify that the attached comprises an accurate translation into English of Japanese Patent Application No. 2003-069602 filed March 14, 2003.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

September 27, 2005

Date

Masaaki IWAMI

【Document Name】 Application for Patent

【Reference No.】 0290819108

【Filing Date】 March 14, 2003

【Destination】 Commissioner, Patent Office

【International Patent Classification】 H01L 33/00

H01L 29/41

H05B 33/28

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【Designation of Charge】

【Ledger No. for Prepayment】 076186

【Amount of Payment】 21,000 yen

【List of Filed Document】

【Object Name】 Specification 1

【Object Name】 Drawing 1

【Object Name】 Abstract 1

【Number of Comprehensive Power of Attorney】 0011610

【Necessity of Confirmation】 Necessary

[Name of Document] Specification

[Title of the Invention] Light-emitting device, light-emitting apparatus, image display apparatus, method of manufacturing light-emitting device, and method of manufacturing image display apparatus

[What is Claimed is]

[Claim 1] A light-emitting device characterized by comprising:

a light-emitting device main body having a light output surface and transferred, and

a transparent electrode formed in a size larger than the size of said light output surface so as to cover said light output surface and connected directly to the whole area of said light output surface.

[Claim 2] The light-emitting device as set forth in claim 1, characterized in that

said transparent electrode provides direct connection between a wiring for supplying electric power to said light-emitting device main body and said light-emitting device main body.

[Claim 3] A light-emitting device comprising:

a light-emitting device main body having a light output surface, and

a transparent electrode formed in a size larger

than the size of said light output surface so as to cover said light output surface, characterized in that

said light-emitting device main body is provided in the form of a chip comprised of a plurality of semiconductor layers, and

said transparent electrode is connected directly to the whole area of said light output surface and connected to side surfaces of said semiconductor layer including said light output surface.

[Claim 4] The light-emitting device as set forth in claim 3, characterized in that

said transparent electrode is connected to side surfaces of said semiconductor layer including said light output surface through a contact layer.

[Claim 5] The light-emitting device as set forth in claim 3, characterized in that

the refractive index of said transparent electrode is lower than the refractive index of said semiconductor layer including said light output surface and is higher than the refractive index of a resin layer provided on the upper side of said transparent electrode.

[Claim 6] The light-emitting device as set forth in claim 3, characterized in that

said transparent electrode is formed by coating

said light output surface with a paste containing conductive particulates dispersed in a light-transmitting resin.

[Claim 7] The light-emitting device as set forth in claim 6, characterized in that

said conductive particulates scatter light emitted from said light output surface and diffuse said light from said transparent electrode to the exterior of said device.

[Claim 8] The light-emitting device as set forth in claim 6, characterized in that

said conductive particulates are formed of indium tin oxide.

[Claim 9] A light-emitting device characterized by comprising:

a light-emitting device main body having a light output surface, and

a transparent electrode formed in a size larger than the size of said light output surface so as to cover said light output surface and connected directly to the whole area of said light output surface.

[Claim 10] A light-emitting apparatus characterized by comprising:

a plurality of light-emitting device main bodies

each having a light output surface and transferred, and

a transparent electrode formed to be larger in size than said light output surfaces so as to cover said light output surfaces and connected directly to the whole areas of said light output surfaces.

[Claim 11] The light-emitting apparatus as set forth in claim 10, characterized in that

said transparent electrode is formed collectively on said light output surfaces of said plurality of light-emitting device main bodies.

[Claim 12] The light-emitting apparatus as set forth in claim 10, characterized in that

said transparent electrode is formed by coating said light output surfaces with a paste containing conductive particulates dispersed in a light-transmitting resin.

[Claim 13] The light-emitting apparatus as set forth in claim 12, characterized in that

said conductive particulates scatter light emitted from said light output surfaces and diffuse said light from said transparent electrode to the exterior of said apparatus.

[Claim 14] An image display apparatus characterized by comprising an image display surface formed by arranging a

plurality of light-emitting devices on an apparatus substrate, each of said light-emitting devices comprising a light-emitting device main body having a light output surface and transferred, and a transparent electrode formed in a size larger than the size of said light output surface so as to cover said light output surface and connected directly to the whole area of said light output surface.

[Claim 15] A method of manufacturing a light-emitting device, characterized by comprising the steps of:

transferring a light-emitting device main body having a light output surface onto a resin portion so as to expose said light output surface,

forming a resist film on said light output surface and the surface of said resin portion,

providing said resist film with an opening portion larger in size than said light output surface so that said opening portion fronts on said light output surface, and

forming a transparent electrode in said opening portion so that said transparent electrode is connected directly to the whole area of said light output surface.

[Claim 16] The method of manufacturing a light-emitting device as set forth in claim 15, characterized in that

said opening portion is so formed as to front on a wiring for supplying electric power to said light-emitting device main body, and said light output surface and said wiring are connected directly to each other through said transparent electrode.

[Claim 17] A method of manufacturing a light-emitting device, characterized by comprising the steps of:

forming a resist film on a light output surface of a light-emitting device main body,

providing said resist film with an opening portion larger in size than said light output surface so that said opening portion fronts on said light output surface, and

forming a transparent electrode in said opening portion so that said transparent electrode is connected directly to the whole area of said light output surface.

[Claim 18] A method of manufacturing an image display apparatus, characterized by comprising the steps of:

transferring a plurality of light-emitting device main bodies each having a light output surface onto a resin portion so as to expose said light output surfaces,

forming a resist film on said light output surfaces and the surface of said resin portion,

providing said resist film with an opening portion

larger in size than said light output surfaces so that said opening portion fronts on said light output surfaces, and

forming a transparent electrode in said opening portion so that said transparent electrode is connected directly to the whole areas of said light output surfaces.

[Claim 19] The method of manufacturing an image display apparatus as set forth in claim 18, characterized in that

said opening portion is so formed as to front on a wiring for supplying electric power to said plurality of light-emitting device main bodies, and said light output surfaces and said wiring are connected to each other collectively through said transparent electrode.

[Detailed Description of the Invention]

[0001]

[Technical Filed to which the Invention Pertains]

The present invention relates to a light-emitting device, a light-emitting apparatus, an image display apparatus, a method of manufacturing a light-emitting device, and a method of manufacturing an image display apparatus. More particularly, the present invention relates to a light-emitting device, a light-emitting apparatus, an image display apparatus, a method of

manufacturing a light-emitting device, and a method of manufacturing an image display apparatus in which light emission efficiency is prevented from being lowered and an electrode is formed for minute light-emitting device main bodies with high accuracy.

[0002]

[Prior Art]

At present, in electronic apparatuses and the like, there have been widely used those configured by arranging a multiplicity of minute devices, electronic component parts, electronic devices, and electronic component parts obtained by embedding these in an insulator such as a resin. For example, in the case of assembling an image display apparatus by arranging light-emitting devices in a matrix form, conventionally, there has been practiced a method of forming the devices directly on a substrate as in the cases of a Liquid Crystal Display apparatus (LCD) and a Plasma Display Panel (PDP) or a method of arranging single Light-Emitting Diode (LED) packages as in the case of an LED display.

[0003]

Besides, since LEDs as light-emitting devices are expensive, an image display apparatus using the LEDs can be manufactured at low cost by manufacturing a large

number of LED chips from one sheet of wafer. When the LEDs are miniaturized from the conventional size of about 300 μm square to a size of several tens of micrometers square and are connected to produce an image display apparatus, it is possible to lower the price of the image display apparatus. An electrode for such a minute light-emitting device is in many cases produced by a method in which a metallic film is formed as the electrode at a part of a light output surface of a light-emitting device main body, and the electrode is connected to a wiring through a metallic film or a gold wire.

[0004]

On the other hand, the light-emitting device is electrically connected to a wiring for driving the light-emitting device, and emits light from a predetermined light emission region to the exterior of the device. Therefore, it is important to prevent the light output efficiency from being lowered, by ensuring that the light emitted from the light emission region to the exterior of the device is not shielded by the wiring and/or the electrode formed in the light emission region. In view of this, for example, in relation to light-emitting devices such as a planar light-emitting thyristor and an organic EL device, there has been known a technology of forming a

transparent electrode so as not to shield the light emitted from the light emission region. (see, for example, Patent Documents 1 and 2)

[0005]

[Patent Document 1]

Japanese Patent Laid-open No. Hei 9-283801

[0006]

[Patent Document 2]

Japanese Patent Laid-open No. 2002-260843

[0007]

[Problems to be Solved by the Invention]

However, it is difficult to form an electrode accurately at the light output surface in a minute light-emitting device. For example, in the case of forming an electrode for a minute light-emitting device main body in which the size of the light output surface is about 10 μm square or below, an accuracy of within about 10 μm is needed for alignment between the light output surface and the electrode. Besides, even in the case where an electrode is formed at the light output surface by use of a light-transmitting material so as not to lower the light output efficiency, also, the formation of the electrode accurately at the light output surface becomes more difficult as the size of the light-emitting device

becomes smaller. Furthermore, as the size of the light-emitting device is reduced, the connection between the electrode and the light-emitting device main body would become insufficient, possibly leading to a trouble in driving the light-emitting device.

[0008]

The present invention has been made in consideration of the above problems. Accordingly, it is an object of the present invention to provide a light-emitting device, a light-emitting apparatus, an image display apparatus, a method of manufacturing a light-emitting device, and a method of manufacturing an image display apparatus in which light output efficiency concerning the light emitted from a light-emitting device main body is enhanced even in the case of a minute light-emitting device and a required electrode is securely formed for the light-emitting device main body.

[0009]

[Means for Solving the Problems]

In accordance with a first aspect of the present invention, there is provided a light-emitting device including a light-emitting device main body having a light output surface and transferred, and a transparent electrode formed in a size larger than the size of the

light output surface so as to cover the light output surface and connected directly to the whole area of the light output surface. According to the light-emitting device, even where the light-emitting device is minute in size, it is possible to accurately connect the transparent electrode and the light output surface to each other, and to suppress the possibility of various troubles such as contact failure in driving the light-emitting device. Furthermore, the transparent electrode does not shield the light emitted from the light output surface, and the light output efficiency can be enhanced, as compared with the case where the light is shielded by a metallic electrode.

[0010]

In the light-emitting device as above, the transparent electrode preferably provides direct connection between a wiring for supplying electric power to the light-emitting device main body and the light-emitting device main body. According to such a transparent electrode, it is unnecessary to connect the electrode formed for the light-emitting device main body to the wiring through a separately formed connection wire, and the direct connection between the light-emitting device and the wiring through the transparent electrode

promises accurate connection between the electrode and the wiring even where the light-emitting device is minute in size.

[0011]

In accordance with a second aspect of the present invention, there is provided a light-emitting device including a light-emitting device main body having a light output surface, and a transparent electrode formed in a size larger than the size of the light output surface so as to cover the light output surface. The light-emitting device main body is provided in the form of a chip composed of a plurality of semiconductor layers, and the transparent electrode is connected directly to the whole area of the light output surface and connected to side surfaces of the semiconductor layer including the light output surface. According to such a light-emitting device, particularly, the ratio of the area of the side surfaces to the area of connection between the transparent electrode and the light-emitting device main body is relatively increased as the light-emitting device becomes minuter in size. Therefore, by forming the transparent electrode not only on the light output surface but also on the side surfaces, it is possible to increase the area of connection between the light-

emitting device main body and the transparent electrode, and to enhance the reliability of the connection condition between the light-emitting device main body and the electrode.

[0012]

Further, in the light-emitting device as above, the transparent electrode is preferably connected to the side surfaces of the semiconductor layer including the light output surface through a contact layer. According to such a light-emitting device, by making the connection through the contact layer, it is possible to further enhance the connection performance between the transparent electrode and the light-emitting device main body, and to provide a light-emitting device having high reliability.

[0013]

In addition, in the light-emitting device as above, preferably, the refractive index of the transparent electrode is lower than the refractive index of the semiconductor layer including the light output surface and is higher than the refractive index of a resin layer formed on the upper side of the transparent electrode. According to such a transparent electrode, light output efficiency can be enhanced, as compared with the case where light is reflected at the interface between the

light-emitting device main body and a resin layer directly covering the light-emitting device main body.

[0014]

Furthermore, in the light-emitting device as above, the transparent electrode is preferably formed by coating the light output surface with a paste containing conductive particulates dispersed in a light-transmitting resin. By applying such a paste directly to the light output surface of the light-emitting device, it is possible to connect the light-emitting device main body and the transparent electrode to each other while generating little gap therebetween. Further, when the paste is applied, the paste goes round onto the side surfaces of the light-emitting device main body, whereby the light-emitting device main body and the transparent electrode can be securely connected to each other.

[0015]

Furthermore, in the light-emitting device as above, preferably, the conductive particulates scatter the light emitted from the light output surface and diffuse the light from the transparent electrode to the exterior of the device. Such conductive particulates can scatter the light coming into the transparent electrode and diffuse the light to a wide range, so that the light can be

emitted from the light output surface to a wide range. Therefore, even if the light-emitting device is minute in size, the light-emitting device can have an apparent light emission surface greater than the actual size of the light-emitting device.

[0016]

In accordance with a third aspect of the present invention, there is provided a light-emitting device including a light-emitting device main body having a light output surface, and a transparent electrode formed in a size larger than the size of the light output surface so as to cover the light output surface and connected directly to the whole area of the light output surface. According to such a light-emitting device, it is possible to accurately connect the transparent electrode and the light output surface to each other even where the light-emitting device is minute in size, and it is possible to enhance light output efficiency, as compared with the case where a metallic electrode is formed.

[0017]

In accordance with a fourth aspect of the present invention, there is provided a light-emitting apparatus including a plurality of light-emitting device main bodies each having a light output surface and transferred,

and a transparent electrode formed to be larger in a size than the light output surfaces so as to cover the light output surfaces and connected directly to the whole areas of the light output surfaces. In such a light-emitting apparatus, even where the light-emitting device main bodies are minute in size, the transparent electrode formed to be larger in size than the light-emitting devices ensures that the transparent electrode can be easily connected to each of the light output surfaces, without accurately forming the transparent electrode relative to the positions of the individual light-emitting devices.

[0018]

In the light-emitting apparatus as above, preferably, the transparent electrode is formed collectively on the light output surfaces of the plurality of light-emitting device main bodies. Therefore, the electrode can be formed on the light output surfaces easily and securely, without forming the electrode individually for each of the light-emitting device main bodies.

[0019]

Further, in the light-emitting apparatus as above, preferably, the transparent electrode is formed by

coating the light output surfaces with a paste containing conductive particulates dispersed in a light-transmitting resin. When such a paste is used, the conductive particulates dispersed in the paste make contact with each other in the transparent electrode and, further, make contact with the light output surfaces, too. Therefore, electrical connection between the light output surfaces and the electrode can be secured.

[0020]

Furthermore, in the light-emitting apparatus as above, preferably, the conductive particulates scatter the light emitted from the light output surfaces and diffuse the light from the transparent electrode to the exterior of the apparatus. With such conductive particulates, it is possible to diffuse to a wide range the light emitted from the light-emitting device main bodies provided as minute light sources, and to emit the light from the whole region of the light emission surface of the light-emitting apparatus.

[0021]

In accordance with a fifth aspect of the present invention, there is provided an image display apparatus including an image display surface formed by arranging a plurality of light-emitting devices on an apparatus

substrate, each of the light-emitting devices including a light-emitting device main body having a light output surface and transferred, and a transparent electrode formed in a size larger than the size of the light output surface so as to cover the light output surface and connected directly to the whole area of the light output surface. According to such an image display apparatus, even where each of the light-emitting device main bodies is minute in size, a larger apparent light emission surface can be obtained, so that light can be emitted from the whole part of the image display surface and image quality can be thereby enhanced.

[0022]

In accordance with a sixth aspect of the present invention, there is provided a method of manufacturing a light-emitting device, including the steps of transferring a light-emitting device main body having a light output surface onto a resin portion so as to expose the light output surface, forming a resist film on the light output surface and the surface of the resin portion, providing the resist film with an opening portion larger in size than the light output surface so that the opening portion fronts on the light output surface, and forming a transparent electrode in the opening portion so that the

transparent electrode is connected directly to the whole area of the light output surface. With the transparent electrode formed in such an opening portion, the transparent electrode can be formed directly for the light-emitting device so as to cover the light output surface, and the transparent electrode can be formed for each light-emitting device easily and securely, without conducting alignment for accurately forming a transparent electrode for a minute light-emitting device.

[0023]

Further, in the method of manufacturing a light-emitting device as above, preferably, the opening portion is so formed as to front on a wiring for supplying electric power to the light-emitting device main body, and the light output surface and the wiring are connected directly to each other through the transparent electrode. With such a transparent electrode, the light-emitting device main body and the wiring can be connected directly to each other. Therefore, where the light-emitting device is minute in size, the light-emitting device main body and the wiring can be securely connected to each other without separately forming a connection wire with high accuracy.

[0024]

In accordance with a seventh aspect of the present invention, there is provided a method of manufacturing a light-emitting device, including the steps of forming a resist film on a light output surface of a light-emitting device main body, providing the resist film with an opening portion larger in size than the light output surface so that the opening portion fronts on the light output surface, and forming a transparent electrode in the opening portion so that the transparent electrode is connected directly to the whole area of the light output surface. According to such a method of manufacturing a light-emitting device, the transparent electrode can be formed accurately, without conducting alignment for forming the transparent electrode for the light-emitting device.

[0025]

In accordance with an eighth aspect of the present invention, there is provided a method of manufacturing an image display apparatus, including the steps of transferring, fixing, and disposing a plurality of light-emitting device main bodies each having a light output surface onto a resin portion so as to expose the light output surfaces, forming a resist film on the light output surfaces and the surface of the resin portion,

providing the resist film with an opening portion larger in size than the light output surfaces so that the opening portion fronts on the light output surfaces, and forming a transparent electrode in the opening portion so that the transparent electrode is connected directly to the whole areas of the light output surfaces. According to such a method of manufacturing an image display apparatus, the transparent electrode can be formed for each light-emitting device, without conducting alignment for forming the transparent electrode for the individual light-emitting devices.

[0026]

In the method of manufacturing an image display apparatus as above, preferably, the opening portion is so formed as to front on a wiring for supplying electric power to the plurality of light-emitting device main bodies, and the light output surfaces and the wiring are connected to each other collectively through the transparent electrode. Therefore, even in the case of an image display apparatus in which a plurality of light-emitting devices are arranged, the connection between the wiring and each of the devices can be easily achieved without lowering the light output efficiency.

[0027]

[Mode for Carrying out the Invention]

Now, a light-emitting device, a light-emitting apparatus, an image display apparatus, a method of manufacturing a light-emitting device, and a method of manufacturing an image display apparatus according to the present invention will be described below, referring to the drawings.

[0028]

First, referring to FIGS. 1 and 2, an example of the light-emitting device according to the present invention will be described. While a light-emitting diode will be taken as an example of the light-emitting device in the description of this example, the light-emitting device according to the present invention is not limited to the light-emitting diode. FIG. 1 is a perspective view showing the condition where a light-emitting diode 1 is disposed on a substrate 2, and FIG. 2 is a sectional view showing the condition where the light-emitting diode 1 is disposed on the substrate 2.

[0029]

As shown in FIGS. 1 and 2, the light-emitting diode 1 is disposed in the state of being fixed to an insulation resin layer 3 formed on the substrate 2, and a transparent electrode 4 is formed directly so as to cover

a light output surface 5.

[0030]

The light-emitting diode 1 is so disposed that an n-type semiconductor layer 6 made to be of the n-type conduction type by doping with an impurity is fixed to the insulation resin layer 3 so as to be exposed from the insulation resin layer 3. The insulation resin layer 3 is formed on the substrate 2, on which a wiring 7 to be connected to the light-emitting diode 1 has previously been formed, and the light-emitting diode 1 is fixedly disposed so as to be connected to the wiring 7. In forming the insulation resin layer 3 after fixingly disposing the light-emitting diode 1 onto the substrate 2, it suffices to remove the insulation resin layer 3 so as to expose the n-type semiconductor layer 6, by etching or the like. While the substrate 2 in this example is an apparatus substrate of an image display apparatus formed by arranging the light-emitting diodes 1, the substrate 2 may be a transfer substrate for temporary transfer of the light-emitting diode(s) 1. The top surface of the n-type semiconductor layer 6 exposed from the insulation resin layer 3 of the light-emitting diode 1 is made to be the light output surface 5, and light generated in the light-emitting diode 1 is emitted to the upper side in the

figures.

[0031]

The light-emitting diode 1 is in the form of a chip, and is made to be a homo-type light-emitting diode or a hetero-type light-emitting diode in which an n-type semiconductor layer and a p-type semiconductor layer are laminated. In this case, the light-emitting diode 1 is not limited to a light-emitting diode having the structure in this example, and may be a light-emitting diode formed by selecting a desired device structure and materials so that it can respectively emit light with one of various wavelengths such as blue, green, yellow, red, infrared, etc. Besides, the light-emitting diode 1 may be a light-emitting diode enhanced in light emission efficiency by forming a double hetero structure or quantum well structure in which an active layer is sandwiched between a p-type clad layer and an n-type clad layer. While the light-emitting diode 1 in this example is a light-emitting diode roughly flat plate-like in shape, the light-emitting diode may be a light-emitting diode in which the lamination direction of the semiconductor layer is inclined against the major surface of the device forming substrate. For example, the shape of the light-emitting diode is not limited to the roughly

flat plate-like shape, and may have any device shape such as the sectional shape of the device is tapered and the outside shape of the device is a hexagonal pyramid. Furthermore, the light-emitting device according to the present invention is not limited to the light-emitting diode, and may be such a light-emitting device as a semiconductor laser device.

[0032]

The transparent electrode 4 is connected directly to the light output surface 5 so as to cover the whole area of the light output surface 5. Further, the transparent electrode 4 is formed to be larger in size than the light output surface 5, and is securely electrically connected to the n-type semiconductor layer 6 including the light output surface 5. Even where the light-emitting diode 1 is minute in size, assured connection between the n-type semiconductor layer 6 and the transparent electrode 4 is achieved. Therefore, electrical connection between the n-type semiconductor layer 6 and the transparent electrode 4 can be performed securely, as compared with the case where it is difficult for the transparent electrode smaller in size than the light output surface 5 to be accurately formed in the region of the light output surface 5. In addition, since

the transparent electrode 4 is larger in size than the light output surface 5, even in the case where the position of the transparent electrode 4 is staggered from the position of the light-emitting diode 1, the electrical connection between the light-emitting diode 1 and the transparent electrode 4 is attained inasmuch as the light-emitting diode 1 is disposed in the region where the transparent electrode 4 is formed.

[0033]

Besides, the transparent electrode 4 is formed to be greater in size than the light output surface 5, thereby providing direct connection between a wiring 8 formed on the surface of the insulation resin layer 3 and the light-emitting diode 1. Therefore, a device main body of the light-emitting diode 1 and the wiring 8 can be connected to each other without performing an intricate step, as contrasted to the case where an electrode is formed on the light output surface 5, and Further, the electrode and the wiring 8 are connected to each other through a connection wire. Particularly, as the light-emitting diode 1 becomes minuter in size, it becomes more difficult to form the electrode and the connection wire in predetermined regions in predetermined sizes. In view of this, according to the transparent electrode 4 formed

as in this example, the light-emitting diode 1 and the wiring 8 can be easily connected without any restriction by the size of the light-emitting diode 1.

[0034]

Further, as an example, the transparent electrode 4 is formed by coating the whole area of the light output surface 5 with a paste containing conductive particulates dispersed in a light-transmitting resin. The conductive particulates are formed, for example, of a light-transmitting and conductive material such as Indium Tin Oxide (ITO), and those which are in a needle shape promising easy scattering of light can be used. When such a transparent electrode 4 is used, the transparent electrode 4 can be connected not only to the light output surface 5 but also to side surfaces 9 of the n-type semiconductor layer 6, in the case where the light-emitting diode 1 is so disposed that the n-type semiconductor layer 6 protrudes from the insulation resin layer 3 as in this example. Further, the light going from the light-emitting diode 1 into the transparent electrode 4 can be scattered by the conductive particulates, thereby emitting the light while diffusing the light to a wide range in the exterior of the device. Thus, with the conductive particulates contained in the transparent

electrode 4, the light-emitting diode 1 can have an apparent light emission area larger than the actual size thereof, so that a light-emitting device preferable for use in a light-emitting apparatus or an image display apparatus can be obtained even where the light-emitting diode is minute in size.

[0035]

In addition, where the n-type semiconductor layer 6 protrudes from the insulation resin layer 3 as in this example, both the light output surface 5 and the side surfaces 9 are connected to the transparent electrode 4, so that it is possible to secure a large area of contact between the transparent electrode 4 and the light-emitting diode 1. Particularly, as the size of the light-emitting diode 1 becomes a minute size of about several tens of micrometers, the ratio of the area of the side surfaces 9 to the area of the n-type semiconductor layer 6 to be connected to the transparent electrode 4 increases. Therefore, if the connection to the transparent electrode 4 can be secured through the side surfaces 9, the electric resistance in the connection region can be reduced, and the light-emitting diode 1 can be made to be a light-emitting device with high reliability. Besides, a contact layer formed of a

metallic material such as Ti may be preliminarily formed on the side surfaces 9. With such a contact layer, it is possible to enhance the performance of contact between the n-type semiconductor layer 6 and the transparent electrode 4, and the light-emitting diode 1 can be made to be a light-emitting device with a further higher reliability.

[0036]

The p-type semiconductor layer 10 is connected to the wiring 7, which is formed on the surface of the substrate 2 and so disposed on the substrate 2 as to be covered by the insulation resin layer 3. While the p-type semiconductor layer 10 is connected directly to the wiring 7 in this example, the n-type semiconductor layer 6 may be connected to the wiring 7. In that case, the transparent electrode 4 is formed on the whole area of the p-type semiconductor layer 10, and the top face of the p-type semiconductor layer 10 constitutes the light output surface.

[0037]

Next, referring to FIG. 3, another example of the light-emitting device according to the present invention will be described. The light-emitting device in this example is a light-emitting diode 19 having a device

structure similar to that of the light-emitting diode described above referring to FIGS. 1 and 2. A p-type semiconductor layer 21 is connected to a wiring 16 formed on a substrate 15. A transparent electrode 18 is formed of a material having a refractive index lower than that of an n-type semiconductor layer 20 having a light output surface 22. Such a transparent electrode 18 can be formed of a light-transmitting material by a film forming method such as sputtering and vacuum vapor deposition. For example, where the light-emitting diode 19 is composed of a GaN-based semiconductor, the n-type semiconductor layer 20 has a refractive index of about 2.4, whereas an ITO film constituting a bulk with a refractive index of about 2.0 is formed as the transparent electrode 18 directly on the light output surface 22. Further, a resin layer 23 having a refractive index of about 1.5 to 1.6 can be formed on the upper side of the transparent electrode 18 as an overcoat layer of the light-emitting diode 19. Therefore, where the light-emitting diode 19 is made to emit light in air whose refractive index is about 1.0, the transparent electrode 18 has a refractive index between the refractive index of the light-emitting diode 19 and the refractive index of the resin layer 23 covering the light-emitting diode 19, whereby the light

reflected at the interface between the light output surface 22 and the resin layer 23 can be reduced, as compared to the case where a resin layer is formed directly on the light output surface 22. Therefore, it is possible to enhance light emission efficiency to the exterior of the device. In addition, by coating the whole area of the light output surface with a paste containing ITO particulates dispersed in a light-transmitting resin, it is possible to form a transparent electrode whose refractive index is lower than the refractive index of the device main body of the light-emitting diode 19 and higher than the refractive index of the resin layer 23. In such a transparent electrode, the light output efficiency can be further enhanced by, for example, admixing the resin with titanium oxide particulates whose refractive index is higher than the refractive index of the GaN-based semiconductor layer.

[0038]

Next, an example of the light-emitting apparatus according to the present invention will be described. FIG. 4 is a sectional view showing the configuration of the light-emitting apparatus according to this example. As shown in FIG. 4, the light-emitting apparatus 25 includes light-emitting diodes 28R, 28G, 28B disposed at a

predetermined device interval in an insulation resin layer 27 formed on a substrate 26. The light-emitting diodes 28R, 28G, 28B are respectively a red light-emitting diode, a green light-emitting diode, and a blue light-emitting diode, which emit light in three primary colors, respectively. These light-emitting diodes are provided as a set, to constitute the light-emitting apparatus 25. The light-emitting diodes 28R, 28G, 28B are formed in a size of about 10 μm square, for example. The surfaces, exposed from the insulation resin layer 27, of the light-emitting diodes 28R, 28G, 28B are made to be light output surfaces of the light-emitting diodes, and a transparent electrode 29 is directly formed so as to cover the whole areas of the light output surfaces. Specifically, by forming the transparent electrode 29 in a size of about 100 μm square, it is possible to directly cover the whole part of the region where the light-emitting diodes 28R, 28G, 28B are disposed, even where the device interval is sufficiently large. Therefore, the transparent electrode 34 is formed collectively, instead of forming electrodes individually for the minute light-emitting devices of about 20 μm square in size. With the transparent electrode 29 thus formed in a size larger than the device size of the light-emitting diodes 28R,

28G, 28B, i.e., the size of the light output surfaces of the devices, it is possible to easily connect the transparent electrode to the light output surface of each device inasmuch as each device is disposed in the region where the transparent electrode 29 is formed. Besides, in this example, the transparent electrode 29 is formed collectively on the light output surfaces of the light-emitting diodes 28R, 28G, 28B so as to constitute a common electrode in driving each of the light-emitting diodes. In addition, the respective devices are individually driven by electric power supplied through wirings separately connected to the light-emitting diodes 28R, 28G, 28B.

[0039]

The transparent electrode 29 is formed from a light-transmitting conductive material such as ITO by a film forming method such as sputtering and vacuum vapor deposition; more preferably, the transparent electrode 29 may be formed by applying an electrode paste containing conductive particulates dispersed in a light-transmitting resin. By use of such a transparent electrode containing the conductive particulates, the light emitted from the light-emitting diodes 28R, 28G, 28B can be emitted while being diffused from a light emission surface 30 of the

light-emitting apparatus 25. Therefore, according to the light-emitting apparatus 25 of this example, the light emission surface 30 can be a light emission surface with a large apparent light emission surface. According to such a light-emitting apparatus 25, the light in red, green, and blue colors can be emitted to a wide range, whereby it is possible to configure a light-emitting apparatus having a large apparent light emission surface, as compared with the actual size of the light-emitting diodes 28R, 28G, 28B, and a sufficient luminance.

[0040]

Next, referring to FIGS. 5(a) to 5(d), a method of manufacturing a light-emitting device according to the present invention will be described, taking the light-emitting diode as an example. First, as shown in FIG. 5(a), a wiring 32 is formed on a substrate 31, and a light-emitting diode 34 is transferred onto the substrate 31 so that a p-type semiconductor layer 34b is connected to the wiring 32. Further, an insulation resin layer 33 is formed so as to cover the substrate 31, the wiring 32, and the light-emitting diode 34. The insulation resin layer 33 is selectively removed so as to expose a light output surface 34c of the light-emitting diode 34 from the insulation resin layer 33. The selective removal of

the insulation resin layer 33 can be conducted, for example, by sandblasting, ashing, or the like. Furthermore, the insulation resin layer 33 may be so removed as to expose the side surfaces of an n-type semiconductor layer 34a including the light output surface 34c of the light-emitting diode 34. In addition, a wiring 35 to be connected to the light-emitting diode 34 in the latter step for driving the light-emitting diode 34 is preliminarily formed on the surface of the insulation resin layer 33 after the selective removal of the insulation resin.

[0041]

Subsequently, as shown in FIG. 5(b), an electrode pattern is formed. A resist film 36 is formed so as to cover both the surface of the insulation resin layer 33 after the selective removal of the insulation resin and the light-emitting diode 34 exposed from the insulation resin layer 33. For example, a photoresist film as the resist film is formed, followed by exposure and development, whereby an opening portion 36a defining the shape of the electrode pattern is formed. The opening portion 36a is formed by removing the resist film 36 so as to expose the whole part of the light output surface 34c of the light-emitting diode 34. Besides, in this

example, the opening portion 36a is so formed as to expose also the wiring 35.

[0042]

Subsequently, as shown in FIG. 5(c), an electrode paste is applied into the opening portion 36a and onto the surface of the resist film 36, to form a transparent electrode layer 37. As the electrode paste for forming the transparent electrode layer 37, a paste containing conductive particulates dispersed in a light-transmitting resin can be used. Besides, the electrode forming material is not limited to the electrode paste used in this example; for example, a resin, which is conductive by itself, may be used as the material. The electrode paste is applied to the light output surface 34c of the light-emitting diode 34 and the wiring 35, which front on the opening portion 36a, so that the light output surface 34c and the wiring 35 are connected to each other collectively through the transparent electrode layer 37.

[0043]

Furthermore, as shown in FIG. 5(d), the transparent electrode layer 37 formed on the resist film 36 is removed, to leave the transparent electrode 38 only in the opening portion 36a. The transparent electrode layer 37 formed on the surface of the resist film 36 can be

removed, for example, by a removing method such as polishing by use of fixed abrasive grains or free abrasive grains, sandblasting, ashing, etc. By forming the transparent electrode 38 in this manner, the transparent electrode 38 is connected also to the side surfaces of the light-emitting diode 34 protruding from the insulation resin layer 33, whereby the connection between the light-emitting diode 34 and the transparent electrode 38 can be securely achieved.

[0044]

Particularly, in the case where a step is generated between the surface of the insulation resin layer 33 and the light output surface 34c of the light-emitting diode 34 protruding from the insulation resin layer 33, the formation of the transparent electrode 38 in the above-mentioned manner makes it possible to enhance the performance of contact between the transparent electrode 38 and the light-emitting diode 34, as compared with the case of forming an electrode film from a transparent electrode material such as ITO by sputtering or vacuum vapor deposition.

[0045]

Further, according to the method of manufacturing a light-emitting device of the present invention, the

transparent electrode 38 is formed on the light output surface 34c of the light-emitting diode 34, whereby the transparent electrode 38 can be securely connected to the light output surface 34c even where the light-emitting diode 34 is a minute light-emitting device with a size of about 10 μm square, and the light output efficiency to the exterior of the device is little lowered. With the opening portion 36a formed to be larger in size than the light output surface 34c of the light-emitting diode 34, the transparent electrode 38 formed in the manner of filling the opening portion 36a and the light output surface 34c are securely connected to each other. Besides, the method of manufacturing a light-emitting device according to the present invention is not limited to that in this example; the electrode paste may also be applied directly to the light output surface of the light-emitting device by a screen printing method using a screen mask provided with an electrode pattern. Incidentally, the method of manufacturing a light-emitting device according to the present invention is preferable also in the case of manufacturing a light-emitting device without performing a transferring step.

[0046]

Next, an image display apparatus and a method of

manufacturing the same according to the present invention will be described. In the following, a method of transferring light-emitting devices will be described first, and then the image display apparatus and the method of manufacturing the same will be described in detail. The method of transferring light-emitting devices according to this example reside in conducting a two-stage pitch-enlarging transfer in which light-emitting devices formed on a first substrate in a high integration degree are transferred onto a temporary holding member so that they are spaced wider apart from each other than they have been on the first substrate, and then the light-emitting devices held on the temporary holding member are transferred onto a second substrate so that they are spaced further wider apart from each other. Incidentally, while the transfer is performed in two stages in this example, a three- or more-stage transfer may also be adopted according to the desired degree of enlargement of device interval.

[0047]

FIGS. 6(a) to 6(d) illustrate basic steps of the two-stage pitch-enlarging transfer method. First, light-emitting devices 40, for example, are densely formed on a first substrate 39a shown in FIG. 6(a). By forming the

light-emitting devices densely, it is possible to increase the number of the devices produced per substrate, and to lower the product cost. The first substrate 39a is any of various device forming substrates such as a semiconductor wafer, a glass substrate, a quartz glass substrate, a sapphire substrate, a plastic substrate, etc., and the light-emitting devices 40 may be formed directly on the first substrate 39a or may be arranged on the first substrate 39a after being formed on another substrate.

[0048]

Next, as shown in FIG. 6(b), the light-emitting devices 40 are transferred from the first substrate 39a onto a first temporary holding member 39b, and are held on the first temporary holding member 39b, which is shown by a broken line. In this instance, the light-emitting devices 40 are spaced wider apart from each other and arranged in a matrix pattern as shown in the figure. The light-emitting devices 40 are so transferred that they are spaced wider apart in x-direction and are spaced wider apart in y-direction perpendicular to the x-direction. The device interval after the wider spacing is not particularly limited, and may be, for example, an interval determined taking into account the formation of

a resin portion and/or the formation of electrode pads in the subsequent step. At the time of transfer from the first substrate 39a onto the first temporary holding member 39b, all of the light-emitting devices 40 on the first substrate 39a may be transferred so that they are spaced wider apart from each other. In this case, the size of the first temporary holding member 39b must only be not less than the size obtained by multiplying the number (in x-direction and y-direction, respectively) of the light-emitting devices 40 arranged in the matrix pattern by the enlarged interval. Also, some of the light-emitting devices 40 on the first substrate 39a may be transferred onto the first temporary holding member 39b while being spaced wider apart from each other.

[0049]

After the first transfer step above-described, as shown in FIG. 6(c), the light-emitting devices 40 present on the first temporary holding member 39b are spaced apart from each other. In view of this, the covering of the surroundings of the device with a resin and the formation of an electrode pad are performed on the basis of each light-emitting device 40. The covering of the surroundings of the devices with the resin is formed for facilitating the formation of the electrode pads, for

facilitating the handling of the devices in the subsequent second transfer step, and the like purposes. The formation of the electrode pads is conducted after the second transfer step followed by the final wiring, as will be described later. Therefore, the electrode pads are formed in a comparatively large size in order to obviate defective wiring. Incidentally, the electrode pads are not shown in FIG. 6(c). By covering the surroundings of each light-emitting device 40 with a resin 40a, a resin-potted chip 40b is formed. The light-emitting device 40 is located roughly in the center of the resin-potted chip 40b. However, the light-emitting device 40 may be located at a position deviated from the center toward one side or one corner of the resin-potted chip 40b. Also in that case, an electrode can be securely connected to the light-emitting device 40 by forming a larger electrode pad as compared with the light-emitting device 40.

[0050]

Next, as shown in FIG. 6(d), the second transfer step is carried out. In the second transfer step, the light-emitting devices 40 arranged in the matrix pattern on the first temporary holding member 39b are transferred onto a second substrate 39c so that the devices 40 are

spaced further apart from each other on the basis of the resin-potted chips 40b.

[0051]

In the second transfer step, also, the adjacent light-emitting devices 40 are spaced wider apart from each other on the basis of the resin-potted chips 40b, and are arranged in a matrix pattern as shown in the figure. The light-emitting devices 40 are transferred while being spaced wider apart from each other in x-direction and in y-direction perpendicular to the x-direction. Assuming that the positions of the devices arranged by the second transfer step correspond to the pixels in a final product such as an image display apparatus, the product obtained by multiplying the original pitch of the light-emitting devices 40 by a roughly integral number is the pitch of the light-emitting devices 40 arranged through the second transfer step. Here, let the magnification factor of the pitch of the light-emitting devices 40 attendant on the transfer from the first substrate 39a onto the first temporary holding member 39b be n and let the magnification factor of the pitch of the light-emitting devices 40 attendant on the transfer from the first temporary holding member 39b onto the second substrate 39c be m, then the value E

of the roughly integral number is represented as $E = n \times m$. Wiring is applied to each of the light-transmitting devices 40 spaced wider apart from each other on the basis of the resin-potted chips 40b on the second substrate 39c. In this case, in order to restrain defective connection as securely as possible, the wiring is conducted by utilizing the previously formed electrode pads and the like. Where the light-emitting devices 40 are light-emitting diodes or the like, for example, the wiring includes the wirings to p-electrode and n-electrode.

[0052]

In the two-stage pitch-enlarging transfer method shown in FIGS. 6(a) to 6(d), the formation of the electrode pads and the potting with a resin can be performed by utilizing the enlarged spaces after the first transfer, and the wiring is conducted after the second transfer. In this case, the wiring is carried out while restraining defective connection as securely as possible, by utilizing the previously formed electrode pads and the like. Therefore, it is possible to enhance the yield of the image display apparatus. In addition, in the two-stage pitch-enlarging transfer method, there are two steps of enlarging the pitch of the devices, and, by

performing the pitch-enlarging transfer in a plurality of steps for spacing the devices wider apart from each other, the number of transferring steps is reduced in practice. For example, let the magnification factor of the pitch attendant on the transfer from the first substrate 39a onto the first temporary holding member 39b be 2 ($n = 2$) and let the magnification factor of the pitch attendant on the transfer from the first temporary holding member 39b onto the second substrate 39c be 2 ($m = 2$), and if the pitch-enlarging transfer should be carried out in a single step, the final magnification factor would be $2 \times 2 = 4$, and there would be need for conducting transfer 16 ($= 4^2$) times, i.e., conducting alignment of the first substrate 16 times. On the other hand, in the two-stage pitch-enlarging transfer method according to this example, the number of times of alignment needed is only 8, i.e., the simple sum of 4 (the square of the magnification factor of 2 in the first transfer step) and 4 (the square of the magnification factor of 2 in the second transfer step). In other words, since $(n + m)^2 = n^2 + 2nm + m^2$, in the case of intending the same pitch magnification factor upon transfer, the two-stage pitch-enlarging transfer method according to this example will necessarily reduce the number of times of transfer by 2nm, as compared with

the single-stage pitch-enlarging transfer method. This promises reductions in the time and cost of the manufacturing steps, by amounts corresponding to 2nm times of transfer, and is particularly profitable where the magnification factor is large.

[0053]

In the second transfer step as above, the light-emitting devices 40 are transferred from the temporary holding member 39b onto the second substrate 39c while being handled as the resin-potted chips 40b. By configuring such resin-potted chips 40b, the surroundings of the light-emitting devices 40 are flattened by the resin 40a, so that the light-emitting devices 40 and the electrode pads can be securely connected to each other by forming the electrode pads larger in size than the light-emitting devices 40, even where the size of the light-emitting devices 40 are as minute as about 10 μm, for example. As will be described later, the final wiring is conducted after the second transfer step. Therefore, defective wiring can be prevented by conducting the wiring by utilizing the electrode pads, which are comparatively large in size.

[0054]

Next, referring to FIGS. 7 to 11, an image display

apparatus and a method of manufacturing an image display apparatus according to the present invention will be described. In this example, a GaN-based light-emitting diode in the shape of a hexagonal pyramid is used as an example of the light-emitting device.

[0055]

First, as shown in FIG. 7, a plurality of light-emitting diodes 42 are formed in a matrix pattern on a major surface of a first substrate 41. The light-emitting diodes 42 may be about 10 μm in size. As a constituent material of the first substrate 41, there is used a material having a high transmittance for the wavelength of laser with which the light-emitting diodes 42 are irradiated, such as a sapphire substrate. For each of the light-emitting diodes 42, components up to p-electrode or the like have been formed, but the final wiring has not yet been formed. Grooves 42g for separation between the devices have been formed, so that the individual light-emitting diodes 42 can be separated. The grooves 42g are formed, for example, by reactive ion etching. Such a first substrate 41 is opposed to the first temporary holding member 43, and selective transfer is conducted, as shown in FIG. 8.

[0056]

A release layer 44 and an adhesive layer 45 in two layers are formed on the surface, opposed to the first substrate 41, of the first temporary holding member 43. As the first temporary holding member 43, for example, a glass substrate, a quartz glass substrate, a plastic substrate, or the like may be used. Examples of the material of the release layer 44 on the first temporary holding member 43 include a fluororesin coat, a silicone resin, a water-soluble adhesive (for example, polyvinyl alcohol [PVA]), and a polyimide. As the adhesive layer 45 on the first temporary holding member 43, a layer of any of ultraviolet ray (UV)-curable adhesives, thermosetting adhesives, and thermoplastic adhesives may be used. As one example, a quartz glass substrate is used as the first temporary holding member 43, a polyimide film 4 μm in thickness is formed as the release layer 44, and thereafter a UV-curable adhesive as the adhesive layer 45 is applied in a thickness of about 20 μm.

[0057]

The adhesive layer 45 on the first temporary holding member 43 is so conditioned that cured regions 45s and uncured regions 45y are mixedly present, and is so registered that the light-emitting diodes 42 to be selectively transferred are located in the uncured

regions 45y. The conditioning for ensuring that the cured regions 45s and the uncured regions 45y are mixedly present may be conducted, for example, by a method in which the UV-curable adhesive is selectively irradiated with UV rays at a pitch of 200 μm by use of an exposure apparatus so that the adhesive is uncured in the regions of transfer of the light-emitting diodes 42 and is cured in the other regions. After such an alignment, the light-emitting diodes 42 at the intended transfer positions are irradiated with laser from the back side of the first substrate 41, and these light-emitting diodes 42 are exfoliated from the first substrate 41 through laser ablation. The GaN-based light-emitting diodes 42 can be exfoliated comparatively easily, since GaN decomposes into metallic Ga and nitrogen at the interface between itself and sapphire. Examples of the laser for irradiation therewith include excimer laser and high-harmonic YAG laser.

[0058]

By the exfoliation utilizing laser ablation, the light-emitting diodes 42 relevant to the selective irradiation are decomposed at the interface between the GaN layer and the first substrate 41, and are transferred in the manner that p-electrode portions thereof pierces

into the adhesive layer 45 on the other side. As for the other light-emitting diodes 42, which are not irradiated with the laser, the corresponding portions of the adhesive layer 45 are the cured regions 45s, and they are not irradiated with the laser, so that the light-emitting diodes 42 are not transferred to the side of the first temporary holding member 43. Incidentally, while only one light-emitting diode 42 is selectively irradiated with laser in FIG. 7, the light-emitting diodes 42 located in the regions spaced apart from the one light-emitting diode 42 by n pitches are also irradiated with the laser in the same manner. By such a selective transfer, the light-emitting diodes 42 the first temporary holding member 43 are arranged on at a pitch greater than the pitch on the first substrate 41.

[0059]

In the condition where the light-emitting diodes 42 are held by the adhesive layer 45 on the first temporary holding member 43, the back side of each light-emitting diode 42 is the n-electrode side (cathode side), and the back side of the light-emitting diode 42 has been deprived of the resin (adhesive) by removal and cleaning. Therefore, when an electrode pad 46 is formed as shown in FIG. 8, the electrode pad 46 is electrically connected to

the back side of the light-emitting diode 42. The back side of the light-emitting diode 42 is made to be a light output surface of the light-emitting diode 42, and the electrode pad 46 is directly formed so as to cover the whole area of the light output surface. In this case, the electrode pad on the cathode side may be about 60 μm square in size. The electrode pad 46 is formed by applying an electrode paste containing conductive particulates dispersed in a light-transmitting resin. Therefore, light emission is not hindered even if the back side of the light-emitting diode 42 is covered by the electrode in a large area, so that a large electrode can be formed. Accordingly, even where the size of the light-emitting diode 42 is about 10 μm square as in this example, the electrode can be formed easily.

[0060]

FIG. 9 shows the condition where the light-emitting diodes 42 have been transferred from the first temporary holding member 43 onto a second temporary holding member 47, via holes 50 on the anode (p-electrode) side have been formed, thereafter anode-side electrode pads 49 have been formed, and the adhesive layer 45 composed of the resin has been diced. As a result of the dicing, device separation grooves 51 are formed, so that the light-

emitting diodes 42 are sectioned on a device basis. The device separation grooves 51, for separation of the light-emitting diodes 42 arranged in a matrix pattern, are composed of pluralities of parallel lines extending in row and column directions in a flat surface pattern. At bottom portions of the device separation grooves 51, the surface of the second temporary holding member 47 is exposed.

[0061]

In addition, a release layer 48 is formed on the second temporary holding member 47. The release layer 48 can be formed, for example, by using a fluororesin coat, a silicone resin, a water-soluble adhesive (for example, PVA), a polyimide, or the like. As an example of the second temporary holding member 47, there can be adopted a so-called dicing sheet, which is composed of a plastic substrate coated with a UV-curable pressure sensitive adhesive and of which the tack is lowered upon irradiation with UV rays.

In conducting the transfer from the first temporary holding member 43 onto the second temporary holding member 47, the release layer 44 formed on the temporary holding member 43 is irradiated with excimer laser from the back side of the temporary holding member 43. Where

the release layer 44 is formed of a polyimide, for example, the irradiation causes exfoliation at the interface between the polyimide and the quartz substrate through ablation of the polyimide, and each light-emitting diode 42 is transferred to the side of the secondary temporary holding member 47. In addition, in forming the anode-side electrode pads 49, the face side of the adhesive layer 45 is etched by oxygen plasma until the surfaces of the light-emitting diodes 42 are exposed. First, via holes 50 can be formed by use of excimer laser, high-harmonic YAG laser, or carbon dioxide laser. In this case, the via holes 50 each have a diameter of about 3 to 7 μm. The anode-side electrode pads 49 are formed of Ni/Pt/Au or the like. The dicing process is conducted by dicing using an ordinary blade, or is conducted by use of the above-mentioned laser where narrow cuts of not more than 20 μm in width are needed. The width of the cuts depends on the size of the light-emitting diodes 42 covered by the adhesive layer 45 formed of the resin in the pixel of the image display apparatus.

[0062]

FIG. 10 shows the condition where light-emitting diodes 42, 61, 62 for three colors of RGB have been arranged on a second substrate 60 and been coated with an

insulation layer 59. When the light-emitting diodes 42, 61, 62 are mounted on the second substrate 60 at staggered color positions by the above-described transfer method, pixels composed of three colors can be formed, with the pixel pitch left unchanged. Examples of the material of the insulation layer 59 include transparent epoxy adhesives, UV-curable adhesives, polyimides, etc. The light-emitting diodes 42, 61, 62 for three colors may not necessary have the same shape. In FIG. 13, the red light-emitting diode 61 has a structure lacking the hexagonal pyramidal GaN layer, and is different in shape from other light-emitting diodes 42 and 62. In this stage, however, the light-emitting diodes 42, 61, 62 have already been covered by the resin-based adhesive to form resin-potted chips, so that the light-emitting diodes 42, 61, 62 can be handled in the same manner although they differ in device structure.

[0063]

FIG. 11 illustrates a step of forming wirings. In the figure, the insulation layer 59 have been provided with opening portions 65, 66, 67, 68, 69, 70, and wirings 63, 64, 71 for connection between the anode and cathode electrode pads of the light-emitting diodes 42, 61, 62 and an electrode layer 57 for wiring of the second

substrate 60 have been formed. In this case, the opening portions, or via holes, can be large in shape because the areas of the electrode pads 46, 49 of the light-emitting diodes 42, 61, 62 are large, and the positional accuracy of the via holes can be rough, as compared with that of via holes formed directly in each light-emitting diode. The via holes may be about $\phi 20\ \mu m$ in diameter, for the electrode pads 46, 49 of about 60 μm square in size. In addition, the depths of the via holes are of three kinds, one for connection to the wiring substrate, one for connection to the anode, and one for connection to the cathode. Therefore, the opening portions are formed in optimal depths by controlling the number of pulses of laser. Thereafter, a protective layer is formed on the wirings, to complete a panel of the image display apparatus. In this case, the protective layer may be formed by use of a material such as a transparent epoxy adhesive, in the same manner as the insulation layer 59 shown in FIG. 11. The protective layer is hardened by heating, to completely cover the wirings. Thereafter, the wiring at a panel end portion is connected to a driver IC, to manufacture a drive panel, thereby completing the image display apparatus.

[0064]

According to the method of manufacturing an image display apparatus in this example, the device interval has already been enlarged when the light-emitting diodes 42 are held on the first temporary holding member 43, so that electrode pads 46, 49 and the like comparatively large in size can be provided by utilizing the enlarged interval. Since wiring is conducted by utilizing the comparatively large electrode pads 46 and 49, the wirings can be easily formed even where the final apparatus size is extremely large as compared with the device size. In addition, in the method of manufacturing an image display apparatus according to this example, the surroundings of the light-emitting devices are flattened by coating with the adhesive layer 45, so that the electrode pads 46 and 49 can be formed with good accuracy. Furthermore, with the electrode pad 46 formed to be larger in size than the light output surface of the light-emitting diode 42, the light-emitting diode 42 can be securely connected to the electrode even where the light-emitting diode 42 is minute in size. Besides, with the electrode provided as a transparent electrode, it is possible to manufacture an image display apparatus with high image quality, without lowering the light output efficiency.

[0065]

[Effects of the Invention]

As has been described above, according to the light-emitting device of the present invention, it is possible to obtain a light-emitting device in which an electrode is securely connected to a light-emitting device main body even where the light-emitting device main body is minute in size, without lowering the light output efficiency of light generated in the light-emitting device main body. In the case of a minute light-emitting device, the light-emitting device and an electrode can be securely connected to each other by forming a transparent electrode larger as compared with the size of the light-emitting device, without conducting accurate alignment relative to an electrode formation region such as a light output surface of the light-emitting device. Further, with such a transparent electrode, even where the wide range of the light output surface is covered directly by the electrode, light output efficiency can be enhanced as compared with the case of forming a metallic electrode opaque to light.

[0066]

In addition, by use of light-scattering conductive particulates contained in the transparent electrode formed so as to cover the light output surface, the light

emitted from the light-emitting device main body can be diffused to a wide range. Therefore, even if the light-emitting device is minute in size, the light-emitting device can have a large apparent light emission surface. Further, with the transparent electrode formed of a material having a refractive index lower than the refractive index of the light-emitting device main body and with a resin layer lower in refractive index than the transparent electrode formed on the transparent electrode, light output efficiency can be enhanced as compared with the case where the resin layer is formed directly on the light-emitting device main body.

[0067]

Besides, the light-emitting apparatus according to the present invention ensures that an electrode can be securely formed for a plurality of light-emitting devices. Further, also in the case where the light-emitting apparatus is produced by arranging a plurality of light-emitting devices, an electrode can be formed collectively, instead of forming respective electrodes for the individual light-emitting devices. Moreover, an electrode can be formed easily and securely even in the case where the accuracy of alignment between the light-emitting devices and the electrode is insufficient.

[0068]

According to the method of manufacturing a light-emitting device of the present invention, even where the reduction in the size of the light-emitting device is advanced, the formation of a transparent electrode so as to directly cover the whole area of the light output surface makes it possible to securely form the transparent electrode for each of the light-emitting devices and to provide a light-emitting device having high reliability.

[0069]

Furthermore, in the image display apparatus according to the present invention, even where pixels are formed by arranging a multiplicity of minute light-emitting devices, a transparent electrode is securely formed without lowering the light output efficiency of each device. Therefore, it is possible to provide an image display apparatus high in image quality and reliability.

[0070]

Besides, according to the method of manufacturing an image display apparatus of the present invention, it is possible to securely form a transparent electrode for minute light-emitting devices, and to manufacture an

image display apparatus on which the cost-basis merit arising from the manufacture of minute light-emitting devices and the merit of an enhanced image quality are reflected sufficiently.

[Brief Description of the Drawings]

[Fig. 1]

FIG. 1 is a perspective view showing the condition where a light-emitting device according to the present invention is disposed on a substrate.

[Fig. 2]

FIG. 2 is a sectional view showing the condition where the light-emitting device is disposed on the substrate.

[Fig. 3]

FIG. 3 is a sectional view showing another example of the light-emitting device according to the present invention.

[Fig. 4]

FIG. 4 is a sectional view showing the structure of a light-emitting apparatus according to the present invention.

[Fig. 5]

FIGS. 5(a) to 5(d) are step diagrams showing the

manufacturing steps of a light-emitting device according to the present invention, in which FIG. 5(a) is a diagram showing a step of disposing the light-emitting device on a substrate, FIG. 5(b) is a diagram showing a step of forming a resist film, FIG. 5(c) is a diagram showing a step of applying an electrode paste, and FIG. 5(d) is a diagram showing a step of forming a transparent electrode.

[Fig. 6]

FIGS. 6(a) to 6(d) are schematic diagrams showing a preferable method of arranging light-emitting devices, which is suitable for a method of manufacturing an image display apparatus according to the present invention.

[Fig. 7]

FIG. 7 is a sectional step diagram showing a first transfer step in the method of manufacturing an image display apparatus according to the present invention.

[Fig. 8]

FIG. 8 is a sectional step diagram showing an electrode pad forming step in the manufacturing method.

[Fig. 9]

FIG. 9 is a sectional step diagram showing an electrode pad forming step after the transfer onto a second temporary holding member in the manufacturing method.

[Fig. 10]

FIG. 10 is a sectional step diagram showing an insulation layer forming step in the manufacturing method.

[Fig. 11]

FIG. 11 is a sectional step diagram showing a wiring forming step in the manufacturing method.

[Description of Reference Symbols]

1, 19, 34, and 42 Light-emitting diode; 2, 15, 26, and 31 Substrate; 3 and 27 Insulation resin layer; 4, 29, and 38 Transparent electrode; 5 and 18 Light output surface; 6 n-type semiconductor layer; 7, 8, 16, 32, 35, and 63 Wiring; 10 p-type semiconductor layer; L Light; 25 Light-emitting apparatus; 30 Light emission surface; 33 Insulation resin layer; 34c Surface; 36 Resist film; 36a and 65 Opening portion; 37 Transparent electrode layer; 39a First substrate; 39b First temporary holding member; 39c and 60 Second substrate; 40 Light-emitting device; 40a Resin; 40b Resin-potted chip; 41 First substrate; 42g Groove; 43 First temporary holding member; 44 Release layer; 45 Adhesive layer; 45y Uuncured region; 45s Region; 46 and 49 Electrode pad; 47 First temporary holding member; 48 Release layer; 49 Anode-side electrode pad; 50 Via hole; 51 Device separation groove; 55 Thermoplastic layer; 57 Electrode layer; 58 Black chrome

layer; 59 Insulation layer

[Name of Document] Abstract of the Disclosure

[Abstract]

[Object] An electrode is securely formed to a light-emitting device, which is minute in size, without lowering the light output efficiency of light.

[Solving Means] A transparent electrode 4 is connected directly to light output surfaces 5 so as to cover the whole areas of the light output surfaces 5. The transparent electrode 4 is formed to be larger in area than the light output surfaces 5, and are securely electrically connected to n-type semiconductor layers 6 including the light output surfaces 5. Even where the light-emitting diodes 1 are minute in size, the n-type semiconductor layers 6 and the transparent electrode 4 are securely connected to each other. As a result, the transparent electrode is formed for the light-emitting diodes 1 more securely as compared to the case where it is difficult to accurately form the transparent electrode smaller in size than the light output surfaces 5 in the light output surfaces 5, and the lights generated in the light-emitting diodes 1 can be outputted to the exterior of the devices without being shielded.

[Selected Drawing] Fig. 2

In the drawings:

[FIGS. 6(a) to 6(d)]

39a... FIRST SUBSTRATE

39b... FIRST TEMPORARY HOLDING MEMBER

39c... SECOND SUBSTRATE

40... DEVICE

40a... RESIN

40b... RESIN-POTTED CHIP

[FIG. 7]

41... FIRST SUBSTRATE

42... LIGHT-EMITTING DIODE

43... FIRST TEMPORARY HOLDING MEMBER

45... ADHESIVE LAYER

45y... UUNCURED REGION

[FIG. 8]

42... LIGHT-EMITTING DIODE

46... ELECTRODE PAD

[FIG. 9]

42... LIGHT-EMITTING DIODE

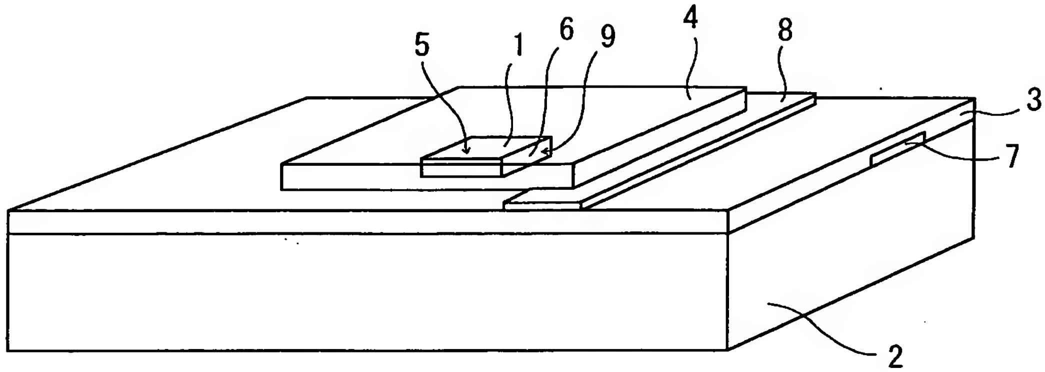
47... SECOND TEMPORARY HOLDING MEMBER

[FIG. 10]

60... SECOND SUBSTRATE

【書類名】　図面

【図１】



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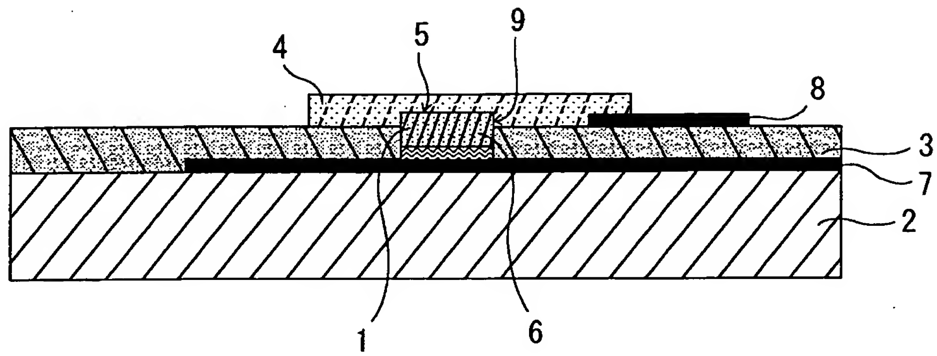

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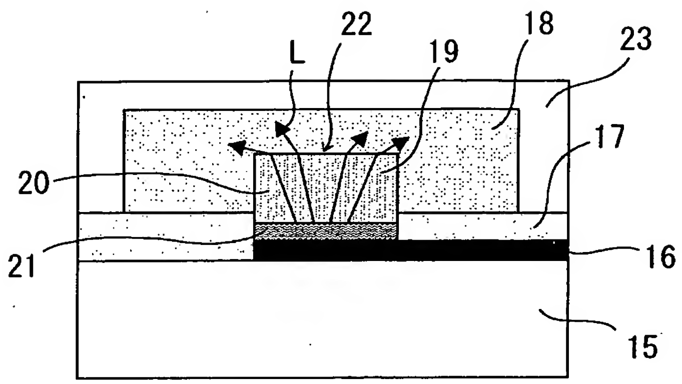

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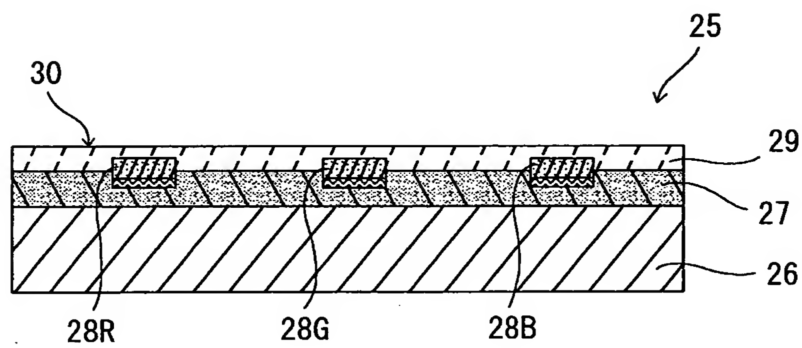

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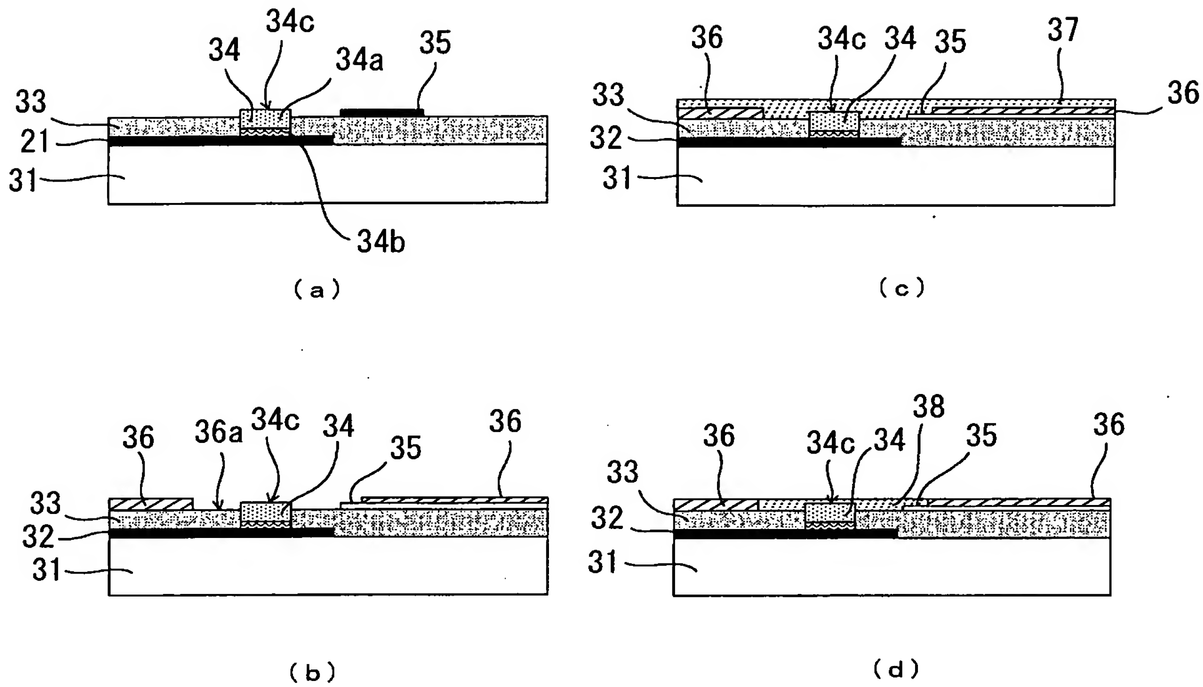
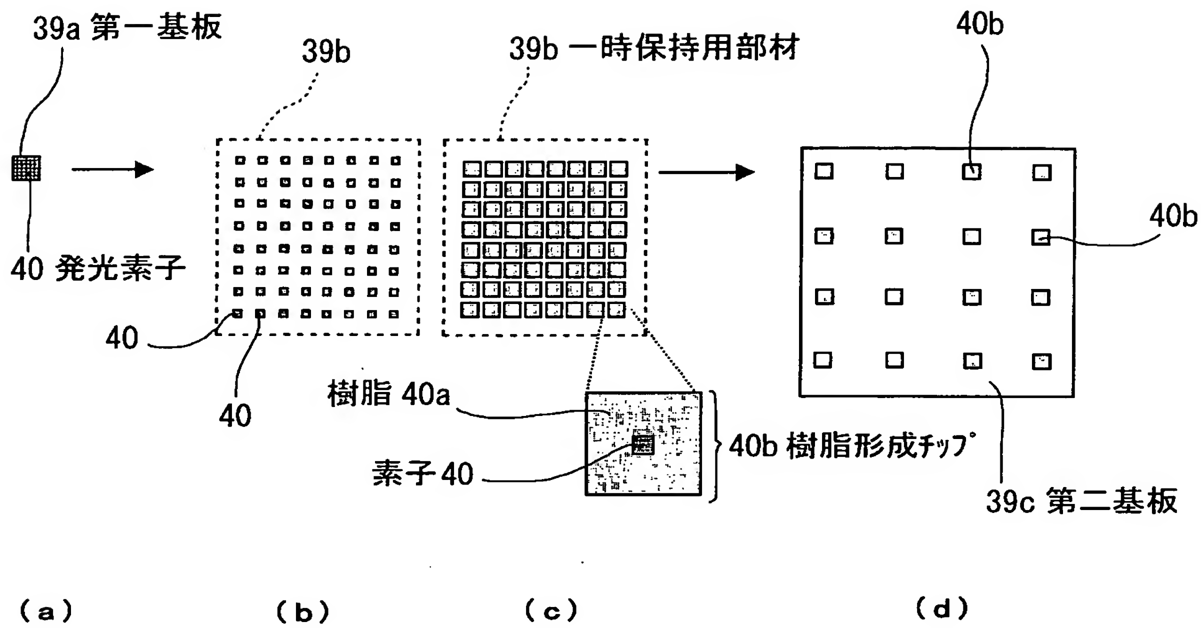
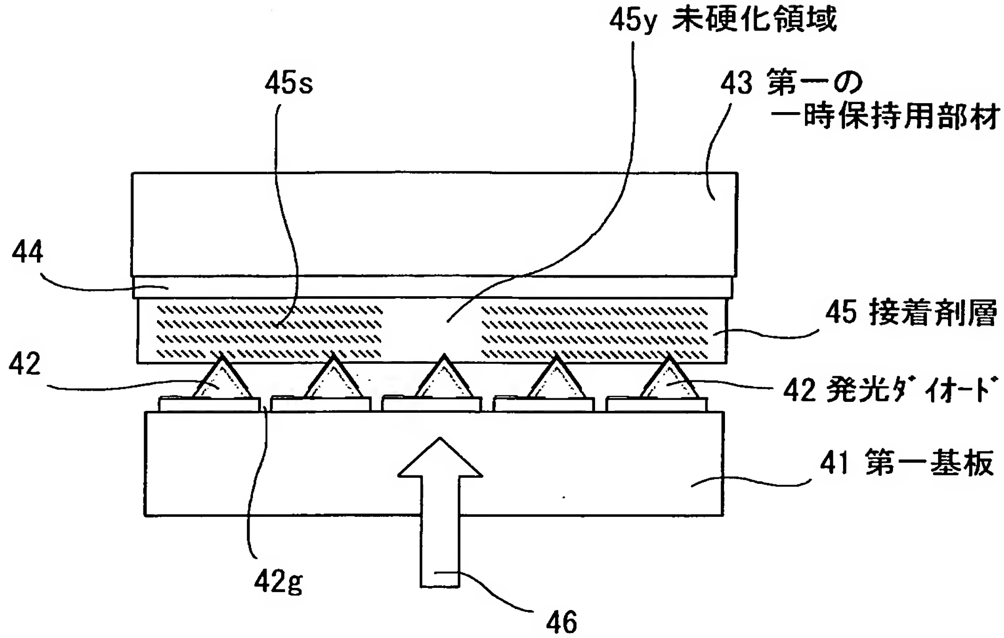

34c
34
34a
35
33
21
31
34b
(a)
36
34c
34
35
37
33
36
32
31
(c)
36
36a
34c
34
35
36
33
32
31
(b)
38
36
34c
34
35
36
33
32
31
(d)

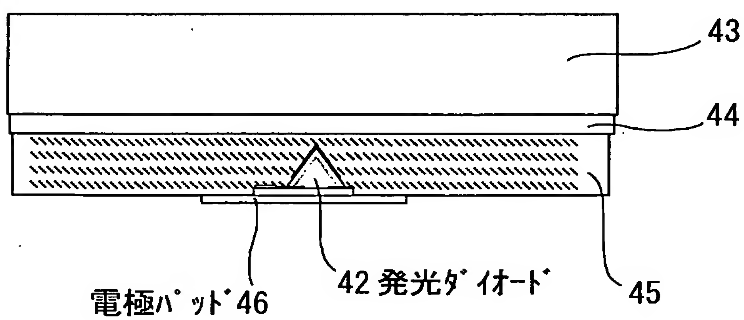
【図６】


39a 第一基板
40 発光素子
40
40
39b
39b 一時保持用部材
樹脂 40a
素子 40
40b 樹脂形成ﾁｯﾌﾟ
40b
40b
39c 第二基板
（a）
（b）
（c）
（d）

【図７】


45y 未硬化領域
45s
43 第一の
一時保持用部材
44
45 接着剤層
42
42 発光ダイオード
41 第一基板
42g
46

【図８】


43
44
電極パッド46
42 発光ダイオード
45

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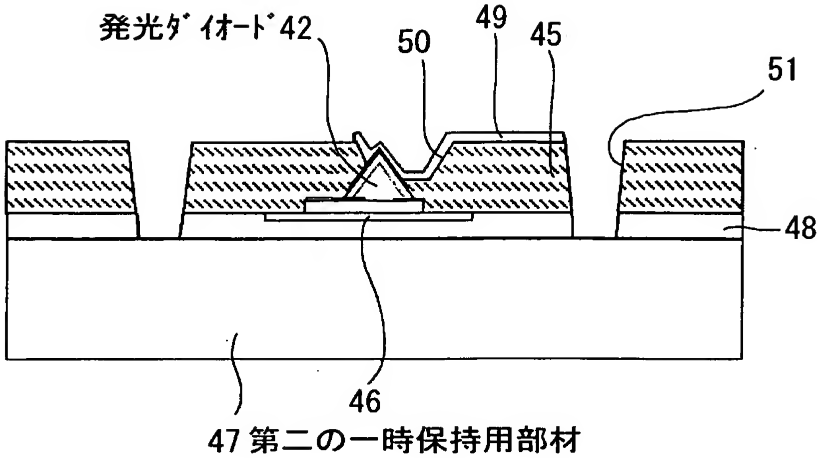

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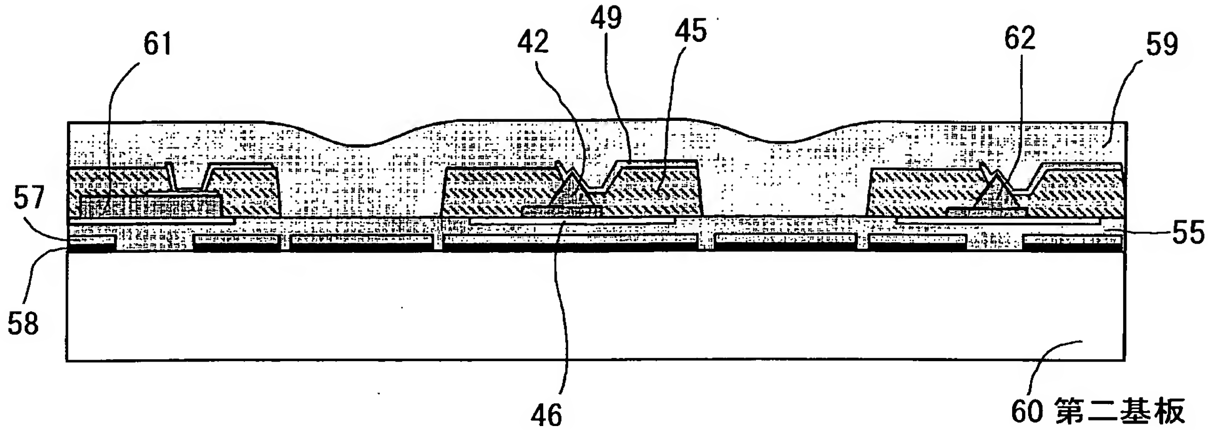

61
42
49
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57
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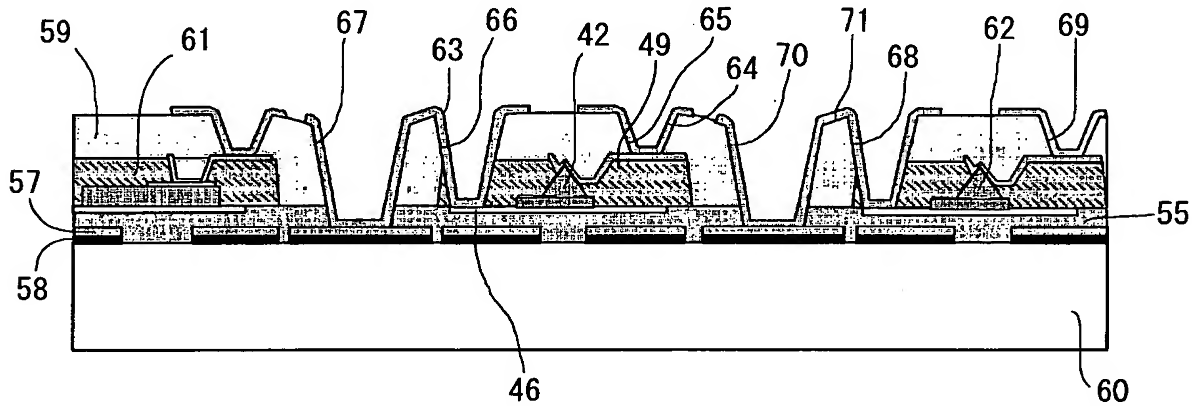
46
60 第二基板

【図１１】



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